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Title:

Area-Normalized Thematic Views

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ABSTRACT

This paper presents a novel technique for dealing with a classic problem that frequently arises in visualization. Very expressive nonlinear transformations can be automatically generated to correct thematic maps so that the areas of map regions are proportional to the thematic variables assigned to them. This helps to eliminate one of the most commonly occurring "visual lies" that occurs in information visualization.

KEYWORDS: visualization, thematic maps, nonlinear magnification, fisheye views

Introduction

Thematic variables are commonly used in cartography to encode additional information within the spatial layout of a map. Common examples of thematic variables are population density, pollution level and birth rate. Such "themes" are normally encoded through the use of color-maps. In this paper we will explore techniques for using this thematic information to directly define spatial transformations in order to make the view more consistent with the thematic encodings. This idea was presented in [1] within the context of a foci-based magnification system, in this paper we will instantiate the idea more fully through the use of a recently developed foci-less system for magnification. These area-normalized views can give rise to rather significant distortions, potentially making it difficult for the viewer to recognize familiar features such as state outlines and other landmarks. A key to the usefulness of these views is the ability to smoothly interpolate between the regular and normalized views of the space, allowing the viewer to interactively realize the relationship between the normal familiar view and the view which more accurately reflects the thematic content.

Nonlinear Magnification Fields

Many approaches have been described in the literature for stretching and distorting spaces to produce effective visualizations. The term nonlinear magnification was introduced in [3] to describe the effects common to all of these approaches.The basic properties of nonlinear magnification are non-occluding in-place magnification which preserves a view of the global context. Leung and Apperley [5] first established the mathematical relationship between 1D magnification and transformation functions for nonlinear magnification, this idea was extended to higher dimensions in [4, 2], resulting in the *nonlinear magnification field*. A method is described in [4] that computes suitable spatial transformations based on a specified scalar field of magnification values. The scalar magnification field is particularly amenable to user and program manipulation, and provides a much more expressive class of transformations than is possible with traditional foci-based approaches to nonlinear magnification such as [1, 3].

Thematic Magnification

The additional expressiveness of nonlinear magnification fields is crucial to the methods we present here; it is now possible to create *data-driven magnifications*[4], where properties of the data are used to directly define the magnification best suited for viewing that data. This capability is a natural match to the color-encoding of thematic variables in maps. We can easily define routines which place a regular grid over a raster image of RGB values, and use the sampled RGB values to derive suitable magnification levels at each point in the grid, producing a magnification mesh as described in [4]. Complex effects can be achieved by encoding different information in each RGB channel; the examples in this paper use the R channel to define the magnification values, and the G channel to specify logical "don't care" values for those areas of the map where the R values are not well defined (e.g. in the bodies of water surrounding geographic regions).

Example I: Interstate Speed Limits

The interstate highway system in the United States covers every state in the union, and each state is able to define the maximum speed limit on those portions of the interstates that pass through it. There is considerable variation in the speed limits chosen, from 55 miles per hour in states such as Connecticut to effectively no speed limit in Montana [1], so that for a driver planning to travel across the USA, the time required for a particular route will be a function of both the geographic distance involved and the speed limits that will be enforced en-route. By encoding the speed limit information for each state as a thematic variable in a map of the USA, we can then sample that map to obtain a suitable magnification field. Here we define magnification as the inverse of the speed limit, so that states with higher speed limits will shrink to reflect the

[1] All speed limits were obtained from a rec.autos.driving FAQ, the numerical speed limit for Montana was arbitrarily set to 140 MPH.

increased rate of travel. Figure 1 shows the thematic encoding of speed limits by state, along with a transformed version of the map which reflects the thematic magnification.

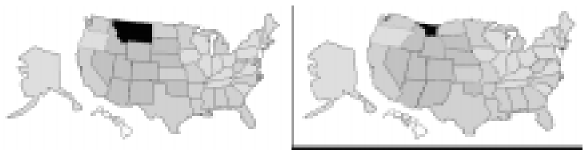

Figure 1: State Speed Limits and Normalized Driving View

Example II: Presidential Election Results

The presidential election in the United States is decided by the number of electoral votes each candidate receives. Each state has a given number of electoral votes (based on the state population), and all of the electoral votes for a single state must be given entirely to only one of the candidates. It is common practice on election day for the news organizations to show a map of the USA, shading a state in blue (or dark gray) if they voted for the Democratic candidate, and red (or light gray) if they voted for the Republican candidate. This gives rise to a classic problem in information visualization that occurs when the area used to visually represent each region is not consistent with the actual thematic variable of importance [6]. Figure 2 shows a traditional view of the presidential election results from 1996. If this image were to accurately reflect the number of electoral votes each candidate received we would expect the ratio of red (light) to blue (dark) pixels to be 0.42; what we actually get however is a ratio of 1.23, an error of 193% which could leave the viewer to mistakenly infer that the Republican candidate (Dole) won the election instead of the Democratic candidate (Clinton). The error occurs because large and sparsely populated states such as Alaska and Montana visually dominate the image even though they have very few electoral votes, while states with a large number of electoral votes such as New York, Texas and California are not represented with an area-emphasis proportional to their electoral contributions.

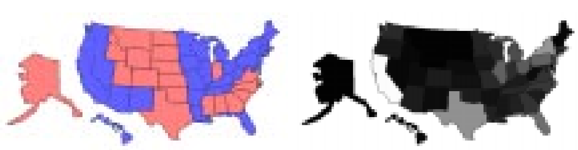

Figure 2: Traditional View of Election Results and Electoral Votes

To reduce this error we can construct a map of the USA where shading is used to represent the number of electoral votes in each state, as shown in the right image of Figure 2. We can then compute a magnification based on that thematic content to transform the normal view of the election into one that more accurately represents the actual proportion of electoral votes received by each candidate. The result is shown in Figure 3, where the ratio of red (light) to blue (dark) pixels is 0.69. Although this still represents an error of 64%, this is less than $1/3$ of the total error found in the original image, and the ratio of pixels now accurately reflects the fact that Clinton won the election.

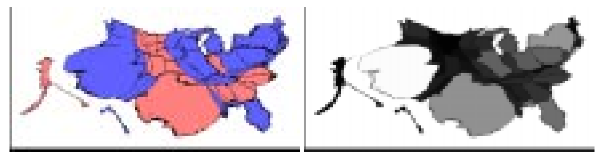

Figure 3: Normalized Views of Election Results and Electoral Votes

Conclusions

Area-normalized thematic views provide a practicable method for reducing one of the most egregious "visual lies" encountered in visualization, particularly in the use of thematic maps. Because of the possibility that a thematic map will represent an inherently degenerate specification having no possible solutions[4], this method does not guarantee transformations giving perfect area in all cases. However, it is possible to weight the iterative method in a manner similar to that used in [4] to ensure that areas of highest error will be corrected as much as is possible, thus guaranteeing that the transformed view will at least be an improvement over the original.

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